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A Proposal of New Category, Scotophile Visitors, within Trogloxenes in Korean Limestone Caves

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Abstract: Based on the habitats investigation of cave organisms in Korean limestone caves from 1996 to 2005, cave environments can be divided into four zones such as entrance zone, twilight zone and dark zone including unstable Dark Zone with Varying Temperature (DZVT) and stable Dark Zone with Constant Temperature (DZCT). Cave dwelling organisms can be conventionally divided into a troglobite, a troglophile and a trogloxene depending upon the degree of adaptation to dark cave environments, and each life tends to live in its favorable habitat. Detailed investigation of their habitat adaptation patterns for five years in the limestone caves in Korea revealed that troglobites (including stygobites) mostly spend their lifetime in DZCT, however they sometimes migrate to DZVT, but rarely to twilight zone throughout the year. Meanwhile, troglophiles (including stygophiles) spend most of their lifetimes in DZVT, and they tend to migrate to twilight zone or DZCT throughout the year. Among trogloxenes, regular visitors have their own favorable ecological niches to stay in cave. There is also another category of cave organisms that live in twilight zone where organic matter is rich in sediments brought in from the outside. These organisms also tend to migrate to the surface and/or even to DZVT throughout the year. This category of cave organisms tends to be easily found outside and does not seem to be satisfied with stable conditions such as constant temperature and humidity. Therefore, new category may be needed to enlist the habitat patterns of these organisms which were conventionally classified as a trogloxene. Therefore, it is proposed here that new "scotophile" visitors within the category of trogloxenes, should be considered in addition to normal trogloxenes such as bats.

Keywords: cave animal, scotophile, trogloxene, limestone cave, Korea

Introduction

Caves have been commonly regarded as a dark underground environment with constant temperature and humidity. However, the cave environments as habitats for cave organisms can be changed critically depending upon the outside climate, the range of light-penetrating distance into caves, cave dimension and the location of cave entrance. Cave organisms have their own ecological niches in caves depending upon their degrees of adaptation and modes of life. They are conventionally divided into troglobites (including stygobites), troglophiles (including stygophiles) and trogloxenes (including stygoxenes). However, this division has been defined in many different ways and such a strict definition can be often ambiguous (Racovitza, 1907; Moore and Nicholas, 1964; Barr, 1968; Monroe, 1970; Jacson, 1982; Chapman, 1993; Lowe and Waltham, 1995; Mohr and Poulson 1966; Clarke, 1997; Wilkens *et al*., 2000; Culver and White, 2005). Generally troglobites indicate the creatures that inhabit only in caves. They have very reduced pigment (or no pigment) and have very small eyes (or none). Troglophiles may complete their entire life cycles in caves, but they also can live in the outside with cave-like environments. Also, the latter can be regarded as transitional species toward troglobites from the adaptation point of view. Trogloxenes are either regular or another type of cave visitors. However, cave environment where troglophiles are usually believed to inhabit, includes the twilight zone that can be influenced by dark zone and the outside. Thus, other similar cave-like environments on the surface such as basement, humid rock cavity, a pile of plant leaves and tree trunks, rock shelter and deep crevasse within a rock, and microcaverns in soil, can be applied in the similar way for troglophiles (Ueno, 1987, 1995). So new category may be necessary to describe this kind of habitat patterns, compared the trogloxenes, regular cave visitors such as bats.

This new proposal is suggested through the research on the ecologic niches of the cave organisms depending upon the degree of adaptation in limestone caves of Korea and

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the distribution pattern according to the seasonal changes of cave environment.

Materials and Methods

The research of cave organisms and their habitats was carried out from May, 1996 to December, 2008 from the limestone caves in central part of the Korean Peninsula (Gangwon-do, Chuncheongbuk-do and Gyeongsangbuk-do) (Fig. 1). About 200 limestone caves in the central part of the Korean Peninsula were selected for this study. Based on the conditions of different environmental changes, caves were divided into several districts, and the cave organisms found in each district were observed and recorded with seasons. Among the organisms examined in this study, the organisms without pigments and eyes were classified as troglobites, and the organisms with eyes and/or pigments that live in dark zone as troglophiles. Also, the organisms living in a twilight zone that have eyes and pigments were regarded as trogloxenes.

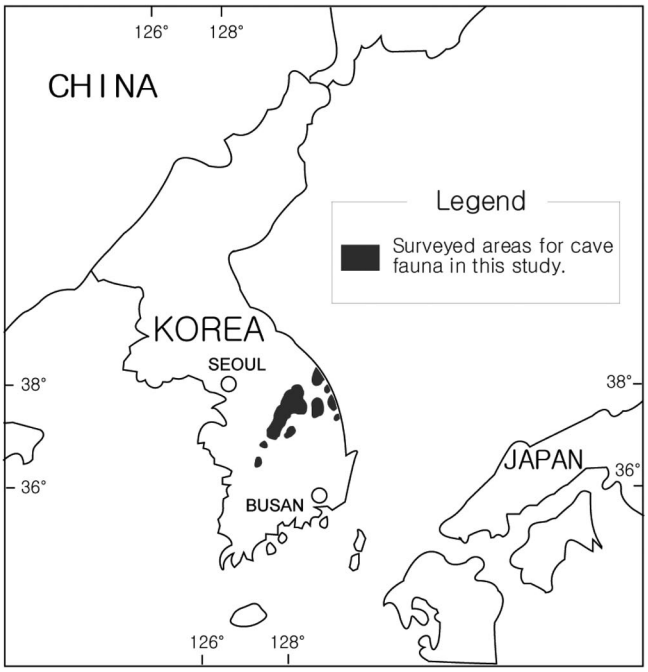

Fig. 1. A map showing the distribution of limestone caves for cave fauna in the Korean Peninsula.

Results and Discussion

Changes in cave environment as well as the outside were monitored, and the diversities and distributions of cave organisms were investigated. Cave environment was divided into entrance zone, twilight zone, DZVT (Dark Zone with Varying Temperature) and DZCT (Dark Zone with Constant Temperature). Depending upon the degree of temperature variation alone, cave environment can be divided into two zones: 1) the zone with varying temperature including entrance zone, twilight zone and dark zone with varying temperature; and 2) the zone with constant temperature (Choi *et al*., 2005) (Fig. 2). Distribution patterns and variabilities of the co-existing cave organisms in different caves were determined by compiling the distribution map of every cave with seasons. The result reveals that the distribution of troglobites, troglophiles and trogloxenes shows systematic trend. Dark zone contains the organisms with reduced pigments and without eyes, the organisms either with reduced pigments or without eyes, and the organisms with pigments and eyes.

Troglobites in this study (i.e., the organisms without pigments and eyes) are present in the entire area of DZCT. However, their population decreases or may be absent in DZVT during dry seasons (autumn, winter and spring) to a great extent. They also tend to migrate toward twilight zone during rainy season (summer) (Fig. 3). They can be also found microcaverns in deep soil.

Troglophiles (the organisms without eyes and/or pigments and the organisms with eyes and pigments that live in dark zone) mostly live in DZVT. However, they tend to migrate toward DZCT during winter and the twilight zone during summer. They can be observed more often than troglobites, and some of troglophiles do not migrate and stay in DZCT

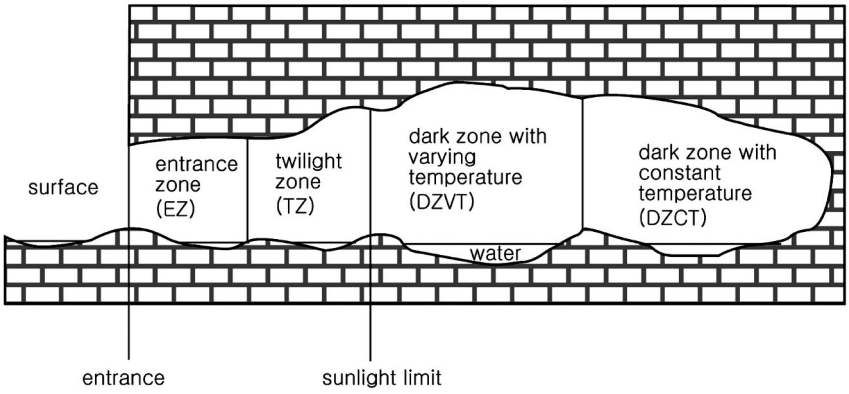

Fig. 2. Ecological zones in limestone caves of Korea.

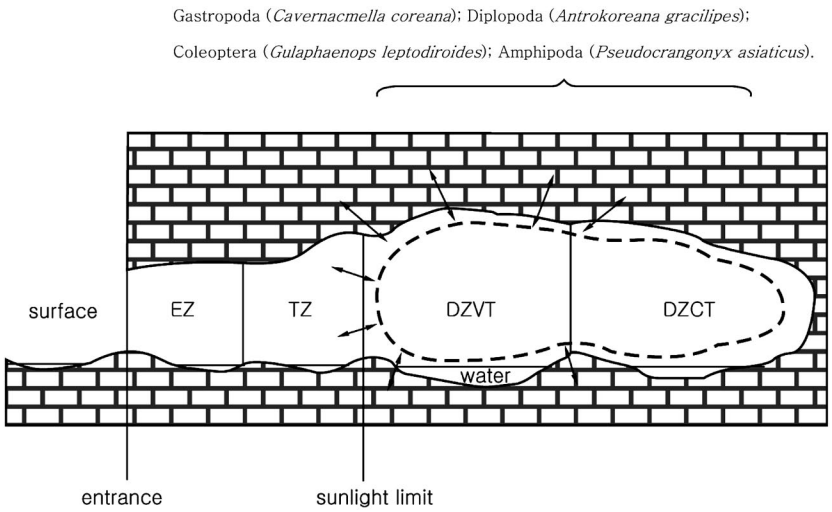

Fig. 3. Distribution pattern of troglobites in limestone caves of Korea.

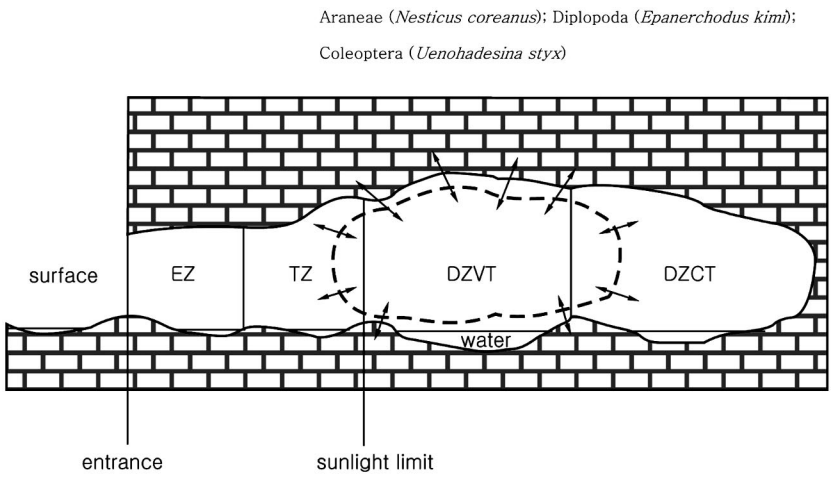

Fig. 4. Distribution pattern of troglophiles in limestone caves of Korea.

for their entire life cycles (Fig. 4). They are also present in rock shelters in deep valley or woods, under the thick pile of tree leaves, or numerous microcavities in soil.

Trogloxenes (regular visitors) show different distribution patterns depending upon their own ecologic habits (Fig. 5). In addition, another type of visitors in caves has eyes and pigment, and tends to be present in shadowed dark zone on the surface such as basement, rocky cavities in woods and valleys, and within a pile of tree leaves and fragments of trunks, and under small rock piles. They tend to live in organic-rich twilight zone, and migrate into dark zone or into the outside with varying temperature during dry seasons and winter (Fig. 6). During summer, they tend to migrate toward the entrance zone.

However, the migration path of even the same species can be quite different depending upon the conditions of cave environment. When a constant cave condition is maintained, they sometimes do not migrate to other places and stay near the entrance zone during winter. Based on distribution pattern, it is believed that the organisms, which live in twilight zone, can be easily found on the surface and their migrations into dark zone are very limited. They also can stay in the outside even during winter. Thus, they are as well adapted as troglophiles, and they are not efficient users of cave environment.

Cave organisms appear to have evolved from the organisms of the pre-adapted state (Moore and Nicholas, 1964). Troglophiles are transitional stage toward troglobites. Twilight-dwelling organisms cannot adapt in caves as efficiently as troglophiles, and do not show the characteristics of cave-dwelling fauna. They can also be easily found in places where there is no direct sunlight. These organisms stay in twilight zone all year round, thus may be in the middle of the evolving stage toward troglophiles.

Depending upon the degree of adaptation to cave environment, cave organisms can be divided as follows:
Trogloxenes

• Regular visitors: Organisms that visit caves regularly as

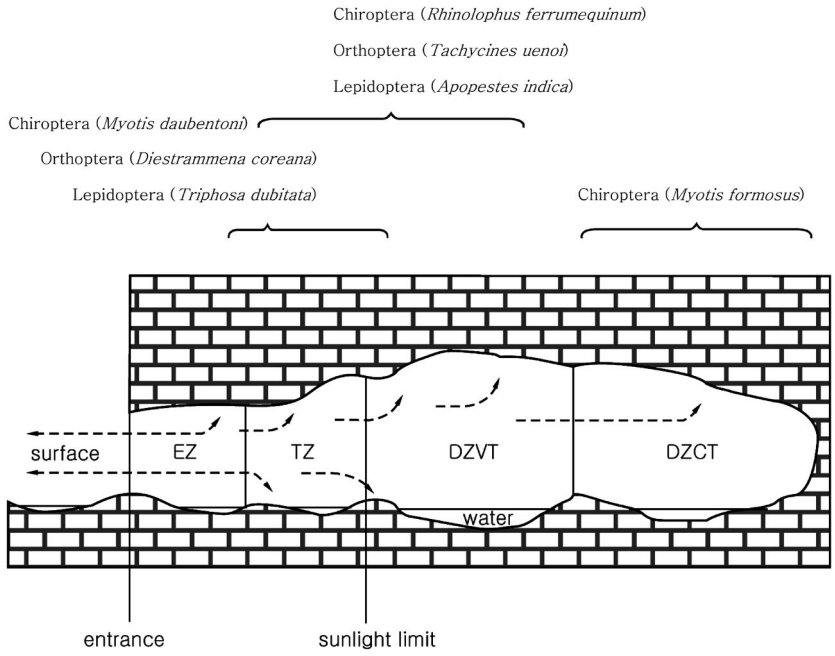

Fig. 5. Distribution pattern of trogloxenes (regular visitors group) in limestone caves of Korea.

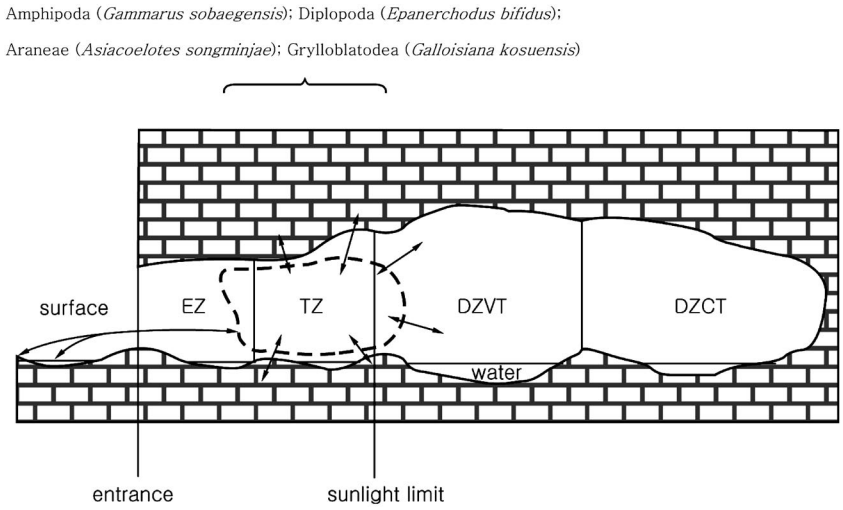

Fig. 6. Distribution pattern of trogloxenes (scotophile visitors group) in limestone caves of Korea.

a part of their life cycles

- Scotophile visitors: Organisms that mostly live in twilight zone, but can be easily found in dimly shadowed areas on the surface. This category is newly proposed in here.

Troglophiles: Organisms with eyes and/or pigments that can live in cave environment, but also inhabit in the similar environment on the surface to the dark zone with variable temperature

Troglobites: Organisms without eyes and pigments that can live only in cave environment

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